DETECTION OF A DEVIATION IN A MATERIAL USING A SPECTRAL CAMERA

FIELD OF THE INVENTION

The present invention relates to analysis of different materials using a visualization method. In particular, the present invention relates to a method, a system and a measurement bar for indicating a deviation in an analyzable material according to a wavelength.

BACKGROUND OF THE INVENTION

Quality control and real-time monitoring is a very important part of industrial production. A particularly challenging situation is, for example, in the production of paper and some other material, where the finished material rolls, at some points at extremely great speeds, to form a finished rolled product. The purpose of quality control and real-time monitoring is to achieve as great a production level as possible while at the same time seeking to produce a product or material whose quality is as good and as consistent as possible.

For example, over the years many different types of methods for the fault indication of a rapidly moving paper web have been developed. The first fault indicators were electromechanical, for example devices based on the metal brushes brushing the surface of the paper and the metal roll on the other side, which gave a fault alarm at the hole points of the paper web. Later there was a shift to using devices based on photoelectric phenomenon and laser.

Optical methods have been found to be very effective in particular with a rapidly moving material, for example in the analysis of a paper web. Optical methods have numerous advantages. The analysis can be made without touching the analyzable material

itself. In addition, the time lapse appearing in measurements is very small. From solutions of known art a large group of optical analysis methods are known.

The newest fault indicators use visualizing methods, for example digital CCD cameras (CCD, Charged Coupled Device) that film the paper web. In filming typically several cameras are used in parallel to achieve an adequate resolution. Visualization methods enable the classing of different types of faults. There no longer necessarily needs to be a hole in the paper web through which a metal bristle manages to touch its opposing piece, rather the fault can be, for example, a difference in colour (darkness difference), streak or rubbish on the surface of the paper or other material to be analyzed.

The above-mentioned visualizing methods work, for example, in the area of visible light which is located typically at wavelengths of 380 nm...780 nm. In visualization methods monitoring can be of either a part of the analyzable material (for example a part of a moving paper web) or the entire material (for example the entire length of a moving paper web). Different visualizing methods have in common that in these methods an attempt is made to visually recognize observable deviations and possibly even the cause of these deviations.

From solutions of known art are known a group of optical methods that are based on the use of spectral data from the analyzable material. In these methods, for example, the wavelengths contained in the light reflected from the analyzable material are measured to determine different quality parameters.

Solutions of known art contain many disadvantages. If the analyzable material is very large in size, for example a moving paper web, which can be as much as 10 metres wide, in practise many cameras are needed to achieve the desired resolution. An addi-

tional problem is that the speed of current solutions is not adequate to accurately analyze material webs moving at high speeds.

The use of several cameras also leads to other problems. If one camera ceases to function, the system in its entirety will not function until the camera has been fixed or replaced. In addition, the use of several cameras increases the construction and use expenses of the monitoring system.

The filming presented in solutions of known art requires a great deal of information processing capacity and a large number of cameras. In addition, the image material produced by the cameras for analysis is huge in size.

In addition, in known methods and systems increasing sharpness and calculation capacity is laborious and requires great monetary investments.

Further, a weakness of known methods and systems is their reliability and maintenance due to sensitive electronic parts and computers, among other things.

OBJECT OF THE INVENTION

The object of the invention is to obviate the above-mentioned disadvantages or at least to significantly lessen them. In particular, the object of the invention is to disclose a new type of method and system wherein using just one camera stationary or moving material can be accurately analyzed.

For the characteristic features of the invention reference is made to the claims.

SUMMARY OF THE INVENTION

The invention relates to a fault indication which is based on the coding of wavelengths. Fault is used to mean any deviation that causes the spectrum formed to deviate from the predetermined setup value.

The invention relates to a method for indicating a deviation in an analyzable material according to a wavelength. In the method, the light produced by the light source is dispersed as several spectrums to the surface of the analyzable moving planar material, the spectrums reflected from the surface of the analyzable moving planar material are collected, the collected spectrums are guided into a spectrum camera, the spectrums guided into the spectrum camera are compared to the predetermined reference spectrum and the location of one or more deviations is defined in the analyzable material on the basis of comparison. The spectrum camera can be either an analogical or digital spectrum camera.

In one embodiment of the invention, the light produced by the light source is dispersed to the surface of the analyzable material as overlapping spectrums in a first and a second direction such that the first and the second direction are essentially perpendicular to one another, the spectrums reflected from the surface of the analyzable material are collected with a lens to the focal point of the lens and the spectrums collected to the focal point are guided by at least one optic fibre into a spectrum camera. In one embodiment of the invention, the light produced by the light source is dispersed to the surface of the analyzable material as overlapping spectrums in a first and a second direction such that the spectrums dispersed in the first and the second direction are formed of different wavelength areas.

In one embodiment of the invention, the light produced by the light source is dispersed by the first lens as a spectrum on the surface of the analyzable material. The light of the light source is guided to the first lens preferably by an optic fibre. The spectrum reflected from the analyzable material is collected with the second lens in a line that comprises

the wavelengths reflected to the surface of the analyzable material. The collected line is guided to a bank of optic fibres, in which each fibre collects a portion of the reflected light. Each fibre is guided as a spatial pixel of the spectrum camera and each spatial pixel is dispersed into a group of spectral components. The data gathered by the spectrum camera is analyzed and the location of a deviation in the analyzed material is defined on the basis of the spatial and spectral components of the pixel of the spectrum camera.

In the method is used preferably a set of measurement modules of which each one contains its own second connection containing a bank of optic fibres, a first lens and a second lens. The set of modules is preferably arranged in a separate measurement bar. The light produced by the light source is guided by the first connection into each measurement module. After this the light produced by the light source is dispersed by the first lens as a spectrum on the surface of the analyzable material such that using the light dispersed through the first lens of each measurement module a particular portion of the area to be analyzed is covered. Correspondingly, the spectrum reflected from the surface of the analyzable material is collected with the second lens of each measurement module in a line that comprises the wavelengths reflected to the surface of the analyzable material covered by each measurement module. Each line is guided to the bank of optic fibres of the second connection of each measurement module.

In one embodiment of the invention, the method uses a set of measurement modules where each one contains the necessary optical components. In this case, in the method, the light produced by the light source is guided by the first connection into each of the measurement modules, the light produced by the

light source is dispersed to the surface of the analyzable material as overlapping spectrums in a first and a second direction such that using the light dispersed through each measurement module a particular portion of the area to be analyzed is covered, the spectrums reflected from the surface of the analyzable material are collected with the lens of each measurement module to the focal point of the lens and the spectrums collected to the focal point are guided into a spectrum camera using at least one optic fibre.

Measurement can be calibrated according to the light source such that the reference point of the analyzable material is lit directly without the light produced by the light source being dispersed as at least one spectrum, the light reflected from the surface of the reference point of the analyzable material is collected as a reference spectrum and a spectral distribution of the light source is defined from the reference spectrum.

In one embodiment of the invention, measurement can be calibrated according to the light source such that the light produced by the light source is dispersed as at least one spectrum on the surface of the reference point of the analyzable material, the light reflected from the surface of the reference point of the analyzable material is collected as a reference spectrum and a spectral distribution of the light source is defined from the reference spectrum.

In one embodiment of the invention, the reference spectrum is averaged and/or median filtered on the basis of new spectral measurements.

The invention also relates to a system for coding a place in an analyzable material according to a wavelength. The system comprises an analyzable moving planar material, at least one light source, at least one spectrum camera, means for dispersing the light produced by the light source as several spec-

trums on the surface of the analyzed moving planar material, means for collecting the spectrums reflected from the surface of the analyzable moving planar material, means for guiding the collected spectrums into the spectrum camera, means for comparing the spectrums guided into the spectrum camera to the predetermined reference spectrum and means for defining the location of one or more deviations in the analyzable material on the basis of the comparison.

In one embodiment of the invention, the system comprises means for dispersing the light produced by the light source to the surface of the analyzable material as overlapping spectrums in a first and a second direction such that the first and the second direction are essentially perpendicular to one another, means for collecting the spectrums reflected from the surface of the analyzable material to the focal point and at least one optic fibre for guiding the collected spectrums into the spectrum camera. In one embodiment of the invention, the system is arranged to disperse the light produced by the light source on the surface of the analyzable material as overlapping spectrums in a first and a second direction such that the spectrums dispersed in the first and the second direction are formed of different wavelength areas.

In one embodiment of the invention, the system comprises at least one first lens, with which the light produced by the light source is dispersed as a spectrum to the surface of the analyzable material, at least one second lens, with which the spectrum reflected from the analyzable material is collected in a line which comprises the wavelengths reflected to the surface of the analyzable material, at least one bank of fibre optics in which each fibre collects a portion of the reflected light, and at least one spectrum camera which has been arranged to receive each fibre as a

spatial pixel and which has been arranged to disperse each spatial pixel as a group of spectral components.

Further, the system comprises at least one data processing device that is arranged to analyze the data gathered by the spectrum camera and define the location of a detected deviation in the analyzed material on the basis of the spatial and spectral components of the pixel of the spectrum camera.

In one embodiment of the invention, the system comprises a set of measurement modules. Each measurement module comprises a first connection which is arranged to receive the light produced by the light source which is relayed via optic fibre. Each measurement module further comprises a first lens, with which the light produced by the light source is dispersed as a spectrum to the surface of the analyzable material such that using the light dispersed through the first lens of each measurement module a particular portion of the area to be analyzed is covered. Correspondingly, each measurement module comprises a second lens, with which the spectrum reflected from the surface of the analyzable material is collected in a line that comprises the wavelengths reflected to the area surface of the analyzable material that is covered by each measurement module. Further, each measurement module comprises a second connection containing a bank of optic fibres, in which each fibre is arranged to collect a portion of the reflected light. The measurement modules are connected to the spectrum camera preferably by an optic fibre.

In one embodiment of the invention, the system comprises a set of measurement modules. Each measurement module comprises a first connection, with which the light produced by the light source is guided to each measurement module, means for dispersing the light produced by the light source to the surface of the analyzable material as overlapping spectrums in a

first and a second direction such that using the light dispersed through each measurement module a particular portion of the area to be analyzed is covered, means for collecting the spectrums reflected from the surface of the analyzable material to the focal point of the lens contained in each measurement module, and a second connection, to which is connected at least one optic fibre which is arranged to connect the measurement module to the spectrum camera for guiding the spectrums collected to the focal point into the spectrum camera.

In one embodiment of the invention, the system comprises a measurement bar, to which the measurement modules are attached. In one embodiment of the invention, the system further comprises means for moving the measurement bar.

The invention also relates to a measurement bar for analyzing the material. The measurement bar comprises at least one measurement module. Each measurement module comprises means for dispersing the light produced by the light source as several spectrums to the surface of an analyzable moving planar material, means for collecting the spectrums reflected from the surface of an analyzable moving planar material and means for guiding the collected spectrums into the spectrum camera.

In one embodiment of the invention, each measurement module comprises a first connection with which the light produced by the light source is guided into each measurement module, means for dispersing the light produced by the light source to the surface of the analyzable material as overlapping spectrums in a first and a second direction such that using the light dispersed through each measurement module a particular portion of the area to be analyzed is covered, means for collecting the spectrums reflected from the surface of the analyzable material to the focal point of

the lens contained in each measurement module, and a second connection, to which is connected at least one optic fibre which is arranged to connect the measurement module to the spectrum camera for guiding the spectrums collected to the focal point into the spectrum camera.

In one embodiment of the invention, each measurement module comprises at least one first lens, with which the light produced by the light source is dispersed as a spectrum to the surface of the analyzable material such that using the light dispersed through the first lens of each measurement module a particular portion of the area to be analyzed is covered. Further, each measurement module comprises at least one second lens, with which the spectrum reflected from the surface of the analyzable material is collected in a line that comprises the wavelengths reflected to the area surface of the analyzable material covered by each measurement module. Each measurement module also comprises a bank of optic fibres that is arranged to collect a portion of the reflected light. The measurement bar also comprises an optic fibre that is arranged to connect the banks of optic fibres to the spectrum camera.

In one embodiment of the invention, each measurement module comprises a first connection which is arranged to receive the light produced by the light source which is relayed via optic fibre, a first lens, with which the light produced by the light source is dispersed as a spectrum to the surface of the analyzable material such that using the light dispersed through the first lens of each measurement module a particular portion of the area to be analyzed is covered, a second lens, with which the spectrum reflected from the surface of the analyzable material is collected in a line that comprises the wavelengths reflected to the area surface of the analyzable material

covered by each measurement module, and a second connection containing a bank of optic fibres, in which each fibre is arranged to collect a portion of the reflected light. To the second connection is connected an optic fibre which is arranged to connect the bank of optic fibres to the spectrum camera.

In one embodiment of the invention, the measurement bar is arranged to be moveable.

In one embodiment of the invention, the measurement bar is located above the analyzable material.

In one embodiment of the invention, the measurement module comprises the first orientation means, with which the first lens is oriented to disperse the light produced by the light source as a spectrum to the desired area of the surface of the analyzable material.

In one embodiment of the invention, the measurement module comprises the second orientation means, with which the second lens is oriented to collect the spectrum reflected from the desired area of the surface of the analyzable material.

In one embodiment of the invention, the measurement module further comprises means for locating the dispersion means to the side such that the analyzable material is lit directly for measurement of a reference spectrum from the reference area of the analyzable material.

The invention further relates to a measurement module for analyzing the material. The measurement module comprises means for dispersing the light produced by the light source as several spectrums to the surface of the analyzable moving planar material, means for collecting the spectrums reflected from the surface of the analyzable moving planar material, and means for guiding the collected spectrums into the spectrum camera.

The analyzable material is, for example, wood, paper, fabric, metal or plastic.

In one embodiment of the invention, the measurement module comprises a first connection, with which the light produced by the light source is guided into each measurement module, means for dispersing the light produced by the light source to the surface of the analyzable material as overlapping spectrums in a first and a second direction such that using the light dispersed through each measurement module a particular portion of the area to be analyzed is covered, means for collecting the spectrums reflected from the surface of the analyzable material to the focal point of the lens contained in each measurement module, and a second connection, to which is connected at least one optic fibre which is arranged to connect the measurement module to the spectrum camera for guiding the spectrums collected to the focal point into the spectrum camera.

In one embodiment of the invention, the first lens comprises at least one prism and/or grating. The first lens is, for example, a so-called PGP-lens which is composed of two prisms with a grating between them. The second lens is, for example, an ordinary cylinder lens, with which the reflected spectrum is collected in a line to the focal point of the lens.

The invention has many advantages in comparison to known art. On the basis of the data saved in the spectrum camera very exact location information is obtained of faults found in the analyzable material in the x- and y-direction, since the location can be defined on the basis of the wavelength coding principle presented in the invention.

A particular advantage of the invention in comparison to known solutions is that using one spectrum camera, a large system, for example a 9,6 metre wide rolling paper web, can be filmed in its entirety.

Additionally, an advantage of the invention is that it is independent on speed. The invention itself functions in principle at the speed of light, and actual maximum speed depends in practice on the speed of the spectrum camera. The speed of the invention is also based on the fact that image supplied by only one camera is processed.

Additionally, the resolution of the analyzable material produced by the invention is excellent, and the sharpness can also be interpolated to make it even sharper.

Because the system presented by the invention is simple in structure, the system is functionally more reliable and less expensive than systems of known art.

Additionally, the solution presented in the invention is easy to adapt, for example expand, in accordance with the requirements of the analyzable material and its possible mobility.

LIST OF FIGURES

In the following the invention is described in detail with the aid of embodiments, wherein

Fig. 1 shows a method according to the invention,

Fig. 2 shows a system according to the invention,

Fig. 3 shows a measurement module according to the invention,

Fig. 4 shows an example according to the invention of guiding data to the spectrum camera,

Fig. 5 shows an advantageous paper web lighting system,

Fig. 6 shows one example according to the invention for indicating a deviation,

Fig. 7 shows another example according to the invention of guiding data into a spectrum camera,

Fig. 8 shows the spreading of a given wavelength area as a spectrum on the surface of the analyzable material according to one embodiment of the invention, and

Fig. 9 shows the spreading of a given wavelength area as a spectrum on the surface of the analyzable material according to one embodiment of the invention.

DETAILED DESCRIPTION OF THE INVENTION

Fig. 1 shows a method according to the invention. According to step 120, the light produced by the light source is dispersed as several spectrums to the surface of the analyzable material. Dispersion is done, for example, using the first lens. The first lens is, for example, a so-called PGP-lens which is composed of two prisms with a grating between them. According to step 122, the spectrums reflected from the surface of the analyzable material are collected. Collection is done, for example, using the second lens. The second lens is, for example, a cylinder lens. The spectrums collected according to step 124 are guided into a spectrum camera. The spectrum camera is preferably a digital spectrum camera. In step 126, the spectrums guided into the spectrum camera are compared to a predetermined reference spectrum. In step 128, the location of one or more deviations in the analyzable material is defined on the basis of comparison.

Fig. 2 shows a system according to the invention for coding a place in the analyzable material according to a wavelength. The system comprises an analyzable material 102. In Fig. 2, the analyzable material is a paper web which rolls forward at a speed of 20 metres per second. The analyzable material can naturally refer to other materials as well.

At the given point of the rolling paper web is arranged a measurement bar 100 which in Fig. 2 is above the paper web along the entire length of the paper web. To the measurement bar 100 is attached a set of measurement modules 18 whose function is described in more detail below. In Figs. 2 and 3 it is assumed that the measurement bar 100 contains 16 measurement modules 18.

The system comprises a light source 10 which produces white light. The white light produced by the light source 10 is supplied to the measurement modules 18 using an optic fibre 12. The system shown in Fig. 2 uses one light source. In this way the problem of having different light sources producing white lights that are somewhat different from one other is avoided. In other words, because only one light source is used, calibration of the measuring system is much simpler. In other embodiments of the invention it is possible to also use several light sources simultaneously.

The measurement modules 18 are connected to the spectrum camera 16 by an optic fibre 14. The spectrum camera 16 for its part is connected to one or more data processing devices 106 which are arranged to analyze the image of the spectrum camera 16. The spectrum camera 16 is preferably a digital spectrum camera. The spectrum camera 16 can also be an analogical spectrum camera, wherein the digital output can be captured from the spectrum camera 16 to the data processing device 106 using a digitalization card.

In the following, the function of the method and system according to the invention are explained in detail with the aid of Figs. 3 and 4. Fig. 3 shows an advantageous embodiment of a measurement module 18 according to the invention. Fig. 4 shows an example of guiding data into the spectrum camera.

As was previously noted, the white light produced by the light source 10 is guided using optic fi-

bre 12 to the first connection 104 of each measurement module 18. The measurement modules 18 are identical to one another in structure as well as function. In the example of Fig. 3, the structure of the measurement modules 18 is simple. They comprise a first connection 104, a first lens 110, a second lens 108 and a second connection 112. With the first connection 104 is referred, for example, to a fibre optic or bundle of fibre optics whose produced light is spread as a chink. With the first lens 110 is referred, for example, to the prism-grating-prism structure (PGP-structure) shown in Fig. 3. The second lens 108 is typically an ordinary cylinder lens. With the second connection is referred, for example, to a connection that comprises a bank of optic fibres.

The white light guided into the measurement module 18 travels through the first lens 110. The first lens 110 disperses the white light as a spectrum to the surface of the analyzable material. Preferably, the spectrum comprises all the colours of the rainbow in the wavelength range $\lambda_1 \ldots \lambda_2$, for example 380 nm...780nm.

It is assumed that the digital spectrum camera 16 used in Fig. 2 takes 200 images per second. It is additionally assumed that the image used in the digital spectrum camera 16 has 640 spatial pixels (horizontal pixels) and 480 spectral pixels (vertical pixels). When it is considered that the speed of the paper web is 20 m/s, it becomes clear that the web is lit in the moving direction of the paper web in 100 mm portions per image to be taken. With the first lens 110 the spectrum reflected to the surface of the paper web reflects back toward the measurement module 18. The second lens 108 is arranged in the measurement module such that it collects the reflected spectrum to the focal point of the lens in a line that contains all the wavelengths reflected to the surface of the

paper web. The line is guided to the bank of optic fibres 112.

In the embodiment shown in Figs. 2, 3 and 4, each bank of optic fibres 112 contains 40 fibres. Thus, one fibre collects in the moving direction of the paper web the light coming from a 2.5 mm (100 mm divided by the number of optic fibres) area. Each measurement module 18 is arranged in the measurement bar 100 such that it lights the paper web over a 600 mm area (area 60 in Fig. 4). Thus, the paper web is lit in 600 mm x 100 mm sized areas. Each of these fibres is guided as a spatial pixel of the spectrum camera 16. Further, each of the spatial pixels is dispersed as 480 spectral components (pixels). In this manner, a 1.25 mm resolution in the cross direction of the paper web is attained and a 2.5 mm resolution in the moving direction of the paper web. Because the measurement bar 100 contains 16 measurement modules 18 which together contain 18 banks of optics 112, they produce a sum of 16x40=640 spatial pixels. In this manner, the entire paper web (width 9600 mm) can be comprehensively filmed by one digital spectrum camera 16. In Fig. 5, the lighting system of the paper web is illustrated in greater detail. The vertical lines drawn inside the 600 x 100 mm box represent the spectrum that is drawn within each box.

The digital spectrum camera 16 is connected to the data processing device 106 which in this example is a computer. The data processing device 106 can also refer to some other device or to a specific part of a computer, for example to a signal processor. From the spectrum image it can be examined using a computer whether some wavelength areas have values that deviate from the norm. In Fig. 4 is shown that at location 62 of the paper web a deviation has occurred. The deviation is transferred, guided by an optic fibre 64, into the spectrum camera. For example the clear dampening

of the reflection factors of some wavelength areas means in practise a hole or other deviation in the paper web at the location that has been lit at the wavelength in question. In Fig. 4 is shown using a XY-delineator that the wavelength λ_1 is clearly dampened in the spectrum reflected from the surface of the paper web.

A simple fault indication of a paper web, used for example to search for holes, is adequate for relatively simple processing. When it is known, for example, what kind of reflection spectrum the paper being examined should have, it is easy to detect certain missing wavelengths, easily by subtraction for instance. Processing can in this way be made very simple and thus also fast, wherein the necessary apparatus (for example a computer or signal processor) requirements are then also reasonable.

As has been presented in the above, the invention is implemented preferably at the wavelengths of visible light. The area of visible light is located at wavelengths 380nm...780nm. In this area reflection factors are affected mostly by the colour of the paper and possible optical brighteners whose function depends on the lighting used. Optical brighteners absorb energy at lower (UV) wavelengths, for example in the range 300nm...400nm and emit energy at longer (blue) wavelengths, for example in the range 450nm...500nm. The result is in practise an optically lighter (bluish) paper.

In the area of visible light can also be used several optic fibres, because the dampening of transmission that occurs at long wavelengths does not need to be considered.

In Figs. 2 and 3, the invention is described using as an example a moving paper web. In other embodiments of the invention the analyzable material may be any other material whatsoever, for example wood,

fabric, metal or plastic. Additionally, it should be noted that the paper to be analyzed does not necessarily need to be moving during analysis. In one embodiment of the invention, both the analyzable material and the measurement system are stationary. In one embodiment of the invention, the analyzable material is stationary, but the measurement system is moved. Although in Fig. 2 only one data processing device 106 is shown, in another embodiment of the invention processing can, if desired, be arranged using several data processing devices 106. Further, although in Fig. 2 only one digital spectrum camera is shown, in another embodiment of the invention two or more cameras can be used. In this manner, resolution can be increased as desired.

In one embodiment of Fig. 3, the measurement module 18 comprises the first orientation means, with which the first lens 110 is orientated to disperse the light produced by the light source as a spectrum to the desired area of the surface of the analyzable material 102. In this manner, the division of the lit area can be fine-tuned. The above-mentioned means can be implemented, for example, by placing the first lens in the desired position mechanically or by some other means that will be obvious to a person skilled in the art.

In one embodiment of Fig. 3, the measurement module 18 comprises the second orientation means, with which the second lens 108 is orientated to collect the spectrum reflected from the desired area of the material. In this manner, the area from which information is collected can be fine-tuned. The above-mentioned means can be implemented, for example, by placing the second lens in the desired position mechanically or by some other means that will be obvious to a person skilled in the art.

In one embodiment of Fig. 3, the measurement module 18 further comprises means for locating dispersion devices to the side such that the analyzable material is lit directly for measurement of a reference spectrum from the reference point of the analyzable material. The above-mentioned means can be implemented, for example, by mechanically turning the first lens to the side or by some other means that will be obvious to person skilled in the art.

Measurement can be calibrated according to the light source, for example, such that the reference point of the analyzable material is lit directly without dispersing the light produced by the light source as at least one spectrum, a reference spectrum is collected from the reflected light from the surface of the reference point of the analyzable material and from the reference spectrum the spectral distribution is defined. Calibration of measurement according to the light source can also be done such that the light produced by the light source is dispersed as at least one spectrum to the surface of the reference point of the analyzable material, a reference spectrum is collected from the light reflected from the surface of the reference point of the analyzable material and from the reference spectrum the spectral distribution is defined. The defined reference spectrum can be averaged and/or median filtered on the basis of new spectral measurements. The reference spectrum is not necessarily revised on the basis of new, actual reference measurements, but rather continuous-timely on the basis of other than fault situation spectrums.

In Fig. 4 is shown one solution for lighting the paper web in sections. There one measurement module 18 of Fig. 1 lights a 600 mm x 100 mm section of the paper web. When measurement modules 18 are arranged 16 units side-by-side, the entire paper web becomes lit. In one embodiment of the invention, the

measurement modules 18 can be arranged in the measurement bar such that several, for example, 100 mm high rows are lit simultaneously. In this case, two overlapping spectral rows do not necessarily need to be spectrally at exactly the same location in the vertical direction.

The measurement system presented in the invention is easy to verify in case of fault situations. Verification is performed, for example, by simultaneously using two digital spectrum cameras, into both of which is guided the same light provided by the optic fibre 14. In one embodiment, both cameras are always in use. In another embodiment, the second camera only starts filming if the function of the first camera becomes disturbed.

In so far as the analyzable material is a rolling paper web, the invention can also be used to locate faults in other parts of the paper machine. Because in the case of a paper web a fault in the paper web can be located in the manner presented above, for example, with 1.25 mm precision in cross direction of the paper web, locating a possible fault in the rollers transporting the paper is also easily possible. Precision can further be interpolated, in other words decided that the fault is between two lines.

Using the invention, the edge location of the wire of the paper machine can simultaneously be defined. The wire is a planar, for example plastic or metal fabric, on top of which the paper web is drained or which supports the web when the paper is drying. The outermost measurement modules of the measurement bar can be turned to light the wire such that the area lit by them extends slightly over the edge of the wire. In this case, the light hitting the wire reflects to the detector (the second lens), but the light going past the wire causes missing wavelengths in the reflection spectrum. In other words, the loca-

tion of the edge of the wire can be discovered in the same manner as the location of a hole in the paper web.

It should be still noted that the above-presented examples of analyzable materials and physical measures of analyzable materials are only exemplary materials and measures. Thus, it is natural that the invention can also be applied to other materials and sizes than those presented in the above.

Due to the invention it is possible, using one digital spectrum camera, to film for example the entire width of a rolling paper web. Resolution can naturally be increased by using more cameras. On the basis of the image of the digital spectrum camera, location information of a fault can be accurately obtained in the x- and y-direction. In other words, in the invention the location is coded according to wavelengths.

The invention produces important information also regarding the quality of the analyzable material. When faults and shortcomings in the analyzable material are analyzed from the image of the digital camera, the quality of the analyzed material can be accurately determined, for example, for a sales organization.

Fig. 6 shows one example of a measurement module 218 according to the invention. The analyzable material 200, for example a paper web, is lit in two directions 220 and 222. The light needed is obtained from optic fibres 223 and 228 through connections 240 and 244. In direction 220 the width is, for example, 400 mm (cross direction) and in direction 222 the height is, for example, 100 mm (machine direction). The areas shown in Fig. 6 can be lit several side-by-side, and thus the number of areas depends on the width of the paper web. In this example, the wavelength of lighting changes in direction 220 in the

wavelength area $\lambda_m \ldots \lambda_n$ and in direction 222 in the wavelength area $\lambda_{n+1} \ldots \lambda_k$. The wavelengths are chosen preferably such that the wavelength areas differ from one another, for example, $\lambda_m < \lambda_n < \lambda_{n+1} < \lambda_k$ in the range 450 nm...1000 nm. As a result of lighting a matrix is formed on the surface of the analyzable material, in which two different wavelengths come into each element of the matrix such that the same combination never occurs twice.

In the first direction 220 the spectrum is produced by the lens 204, the grating 206 and the lens 208 (on the part 234 of the measurement module 218). The aperture 202 is preferably an adjustable circular aperture, with which a point-like light source is produced. Correspondingly, in the other direction 222 the spectrum is produced by the lens 212, the grating 214 and the lens 216 (on the part 236 of the measurement module 218). The aperture 210 is preferably an adjustable circular aperture, with which a point-like light source is produced.

For analysis purposes, the area is filmed using collecting optics (230 and 232) to the focal point (part 238 of the measurement module 218). In this point is then enclosed all the wavelengths reflected from the surface of the paper. The point of light is guided through the connection 242 to the optic fibre 226, with which the light reflected from the surface of the paper is gathered into the input of the spectrum camera. Using the camera the light is dispersed into several spectral components. By comparing the spectrums to a spectrum of a whole, clean paper possible faults can be discovered on the basis of differences in the spectrums.

Fig. 7 shows another example of guiding data into the spectrum camera. In the example of Fig. 7, the analyzable material is lit in areas such that in each area a matrix is formed, wherein two different

wavelengths come into each element of the matrix such that the same combination never occurs twice. The wavelengths are chosen preferably such that the wavelength areas differ from one another, for example, $\lambda_m < \lambda_n < \lambda_{n+1} < \lambda_k$ in the range 450 nm...1000 nm. In the example of Fig. 7, there is a deviation in the analyzable material at the location 72 which hits wavelengths λ_1, λ_2. As was presented in the explanation of the previous figure, the area 70 is filmed using collecting optics to the focal point, and the point is guided using the optic fibre 74 as a pixel of the spectrum camera. When the image of the spectrum camera is analyzed using a computer a clear dampening of reflection factors of any wavelength area would in practise mean a hole or other deviation in the paper web at the location that is lit at the wavelength in question. In Fig. 7 is shown using a XY-delineator that wavelengths λ_1, λ_2 are clearly dampened in the spectrum reflected from the surface of the paper web. On the basis of the dampened wavelengths it is possible to, for example, define accurately the location of the deviation (location 72) in the analyzable material.

Fig. 8 shows the spreading of a certain wavelength area as a spectrum to the surface of the analyzable material in a first direction and Fig. 8 shows the spreading of a certain wavelength area as a spectrum to the surface of the analyzable material in a second direction according to one embodiment of the invention. The wavelength used in the example changes in the x-direction in the range 700 mm...1000 nm and in the y-direction in the range 400 nm...700 nm. The size of the lit area is in this example 0.2 m x 0.2 m.

In Fig. 8 the grating shown has period d = 955 nm, height 1140 nm and the angle of incidence of the light in the air is $\theta_{air} = -16.4°$. Wavelength bands 400 nm...700 nm and 700 nm...1000 nm are produced separately and directed one on top of the other to the

surface of the analyzable material. The focal distances of the lenses f_1 and f_2 are in this example f_1 = 0.03 m and f_2 = -0.01 m. The circular lens f_1 focuses spectral lines to the analyzable material. The cylinder lens f_2 spreads orders of diffraction to the length desired.

The aperture a_1 is an adjustable circular aperture, with which a point-like light source is produced. The best size for the aperture can be determined, for example, by inspecting the spectral distribution. Line aperture a_2 determines the lighting wavelength band and its exact size depends, for example, on the characteristics of the light source. A suitable lighting band is chosen by changing the location of the aperture in the z-direction as well as by adjusting the aperture opening. The width of line aperture a_2 is in this example 0.01-0.05 m.

The arrangement shown in Fig. 9 is identical to the arrangement shown in Fig. 8 with the exception of the different wavelength area which in Fig. 9 is 400 nm...700 nm. In Figs. 8 and 9 as the light source is used for example a thermal light source which produces a band 400 nm...1000 nm. The light is preferably focused onto the aperture a_1 to as small a point as possible. In Fig. 8, ϕ = 51.7° and ψ = 23.1°. In Fig. 8 it is possible to change the location of line aperture a_2 in the z-direction and it is possible to change the location of cylinder lens f_2 in the z-direction. In Fig. 9, ϕ = 72.9° and ψ = 19.3°.

The invention is not limited to only the above-presented embodiments, but many variations are possible without departing from the inventive concept defined by the claims.